

FIZICA MEDIULUI: O Incursiune Spațio-Temporală în Misterele Universului

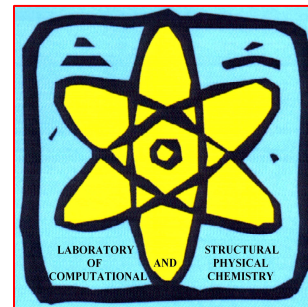
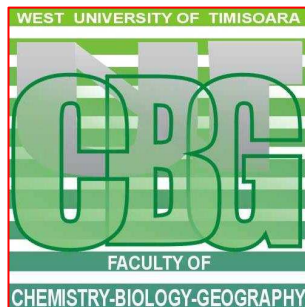
UNIVERSUL: ÎNTRE ENERGIE ȘI NUCLEOSINTEZĂ

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Consecințe Dinamice ale Teoriei Relativității Speciale: Universul, între Energie și Nucleosintează

Relația lui Einstein a Energiei

$$S = \int_a^b L dt$$

$$S = -\alpha c \int_a^b \sqrt{1 - v^2 / c^2} dt$$

$$ds = \underbrace{c dt \sqrt{1 - v^2 / c^2}}_{\text{TIMP PROPRIU}}$$

$$L_{\text{relativist}} = -\alpha c \sqrt{1 - \frac{v^2}{c^2}}$$

$$L_{\text{clasic}} = \frac{m_0 v^2}{2}$$

$$L_{\text{relativist}} = -\alpha c \left(1 - \frac{v^2}{c^2}\right)^{1/2} \underset{v \ll c}{\cong} -\alpha c \left(1 - \frac{1}{2} \frac{v^2}{c^2}\right) = \underbrace{-\alpha c}_{\text{CONSTANȚĂ POTENTIAL}} + \frac{\alpha v^2}{2 c} \cong \frac{\alpha v^2}{2 c} \rightarrow \frac{m_0 v^2}{2} = L_{\text{clasic}}$$

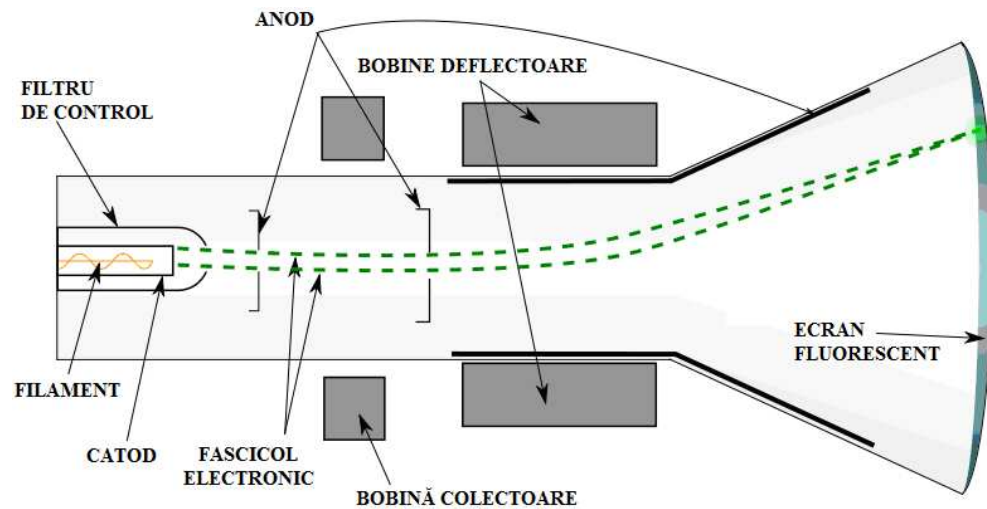
$$\alpha = m_0 c$$

$$L_{\text{relativist}} = -m_0 c^2 \sqrt{1 - \frac{v^2}{c^2}}$$

$$P_{clasic} = \frac{\partial L_{clasic}}{\partial v} = \frac{\partial}{\partial v} \left[\frac{m_0 v^2}{2} - V(q, t) \right] = m_0 v$$

$$P_{relativist} = \frac{\partial L_{relativist}}{\partial v} = -m_0 c^2 \frac{\partial}{\partial v} \left(1 - \frac{v^2}{c^2} \right)^{1/2} = -m_0 c^2 \frac{1}{2} \left(1 - \frac{v^2}{c^2} \right)^{-1/2} \frac{1}{c^2} (-1) 2v$$

$$= \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}} = m_d v$$



$$m_d = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

v/c	$(m/m_0)_{OBS}$	$[(m/m_0)_{CAL}]/[(m/m_0)_{OBS}]$
0.630	1.175	0.988
0.643	1.240	0.988
0.695	1.395	0.988

$$E_{clasic} = p_{clasic} \dot{q} - L_{clasic} = (m_0 \dot{q}) \dot{q} - L_{clasic} = m_0 v^2 - \left[\frac{m_0 v^2}{2} - V(q, t) \right] = \frac{m_0 v^2}{2} + V(q, t)$$

$$E_{relativist} = p_{relativist} \dot{q} - L_{relativist} = (m_d v) v - L_{relativist}$$

$$= \frac{m_0 v^2}{\sqrt{1 - \frac{v^2}{c^2}}} - \left(-m_0 c^2 \sqrt{1 - \frac{v^2}{c^2}} \right) = \frac{m_0 v^2 + m_0 c^2 (1 - v^2 / c^2)}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}} = m_d c^2$$

$$\begin{cases} p = \frac{m_0 v}{\sqrt{1 - v^2 / c^2}} \\ E = \frac{m_0 c^2}{\sqrt{1 - v^2 / c^2}} \end{cases}$$

$$m_e c^2 = \frac{1}{4\pi\epsilon_0} \frac{e_0^2}{r_0} \Rightarrow r_0 = \frac{1}{4\pi\epsilon_0} \frac{e_0^2}{m_e c} = 2.8 \cdot 10^{-15} m$$

$$E = \sqrt{m_0^2 c^4 + p^2 c^2} \quad pc \ll m_0 c^2 \Leftrightarrow v \ll c$$

$$E = (m_0^2 c^4 + p^2 c^2)^{1/2} = m_0 c^2 \left(1 + \frac{p^2 c^2}{m_0^2 c^4} \right)^{1/2} = m_0 c^2 \left(1 + \frac{p^2 c^2}{2m_0^2 c^4} + \dots \right)$$

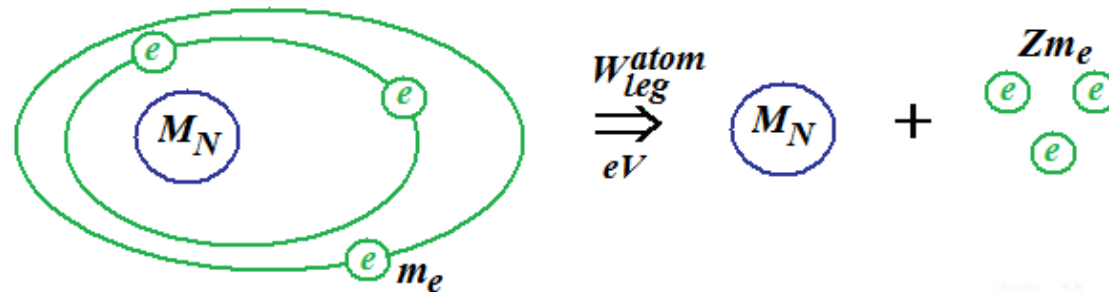
$$\cong m_0 c^2 + \frac{p^2}{2m_0} = m_0 c^2 + \frac{m_0 v^2}{2}$$

Reacții Termonucleare. Nucleosinteza Stelară

$$W_{leg}^N = W_f^N - W_i^N = \underbrace{Zm_p c^2 + (A-Z)m_n c^2}_{W_f^N} - \underbrace{M_N c^2}_{W_i^N}$$



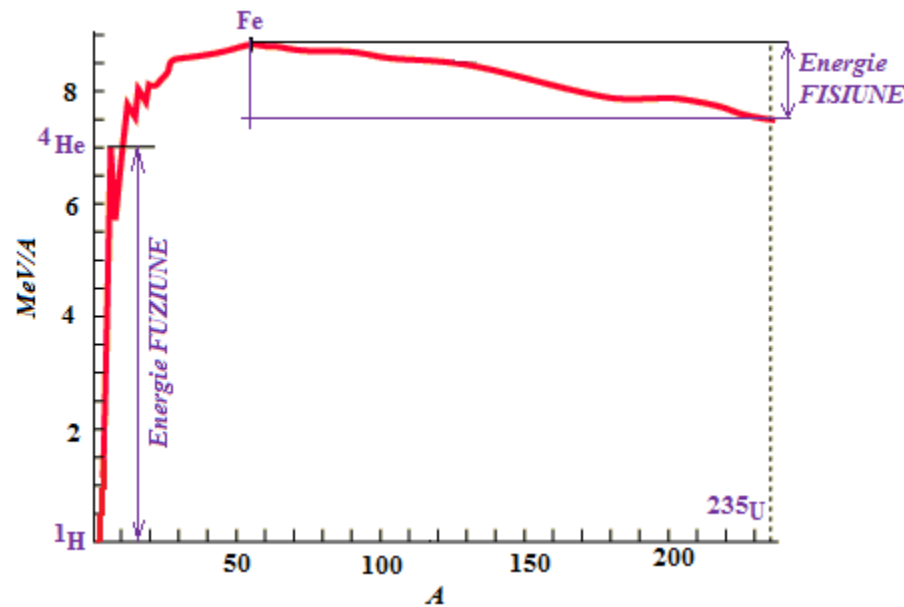
nivelul nuclear
nivelul atomic

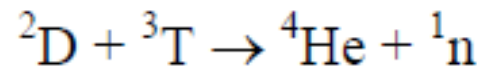
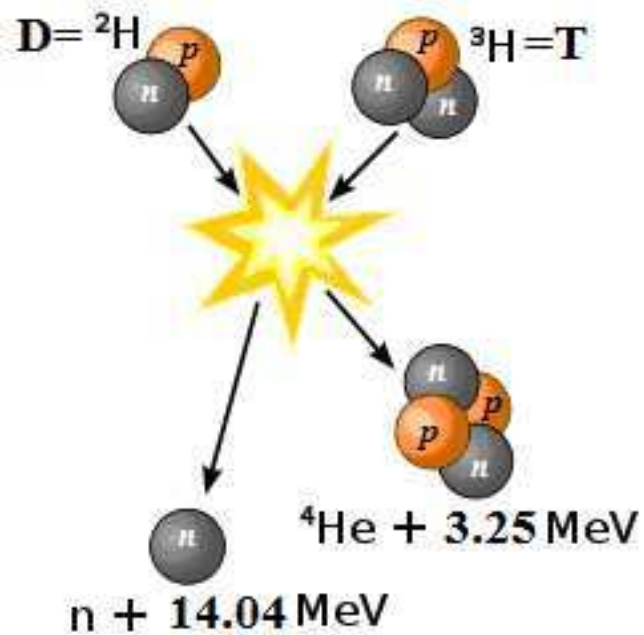


$$W_{leg}^{atom} = \underbrace{M_N c^2 + Zm_e c^2}_{final} - \underbrace{M_A c^2}_{initial} \Rightarrow \underbrace{M_N}_{MeV} = M_A - Zm_e + \underbrace{\frac{W_{leg}^{atom}}{c^2}}_{eV} \cong M_A - Zm_e$$

$$\begin{aligned}
 W_{leg}^N &= Zm_p c^2 + (A-Z)m_n c^2 - M_A c^2 + Zm_e c^2 \\
 &= Zc^2 \underbrace{(m_p + m_e)}_{m(H)} + (A-Z)m_n c^2 - M_A c^2 = [Zm_H + (A-Z)m_n - M_A]c^2 \\
 &\cong 931.5 \underbrace{[Zm_H + (A-Z)m_n - M_A]}_{\text{DEFECT DE MASA}} \text{MeV}
 \end{aligned}$$

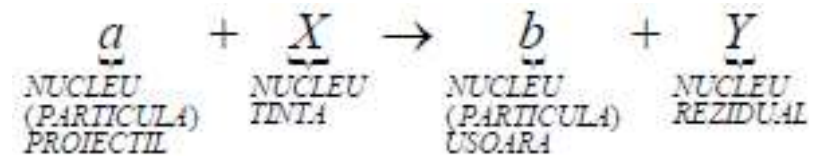
$$B = \frac{W_{leg}^N}{A} \cong 931.5 \frac{Zm_H + (A-Z)m_n - M_A}{A} [\text{MeV}]$$





$$Q_{T(D,n)^4\text{He}} = -17.60[\text{MeV}]$$

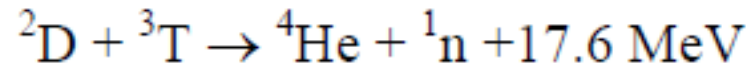
$$\Delta m_{T(D,n)^4\text{He}} = +17.58[\text{MeV}]$$



energia de reacție nucleară

$$Q_{X(a,b)Y} = \sum_{a,X} W_{\text{legatura}}^{\text{initial}} - \sum_{b,Y} W_{\text{legatura}}^{\text{final}}$$

$$\Delta m_{X(a,b)Y} = \sum_{a,X} m^{\text{initial}} - \sum_{b,Y} m^{\text{final}}$$

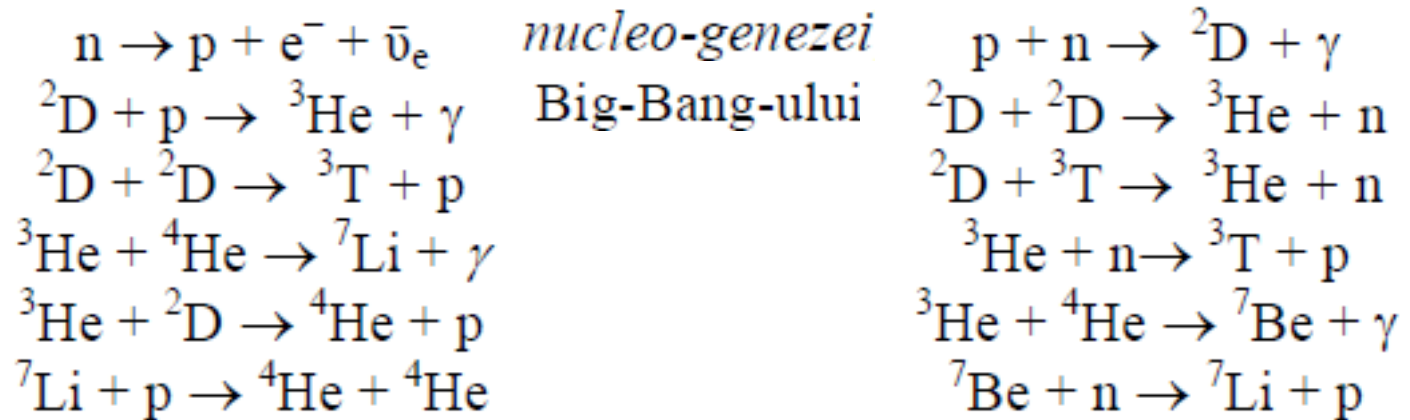


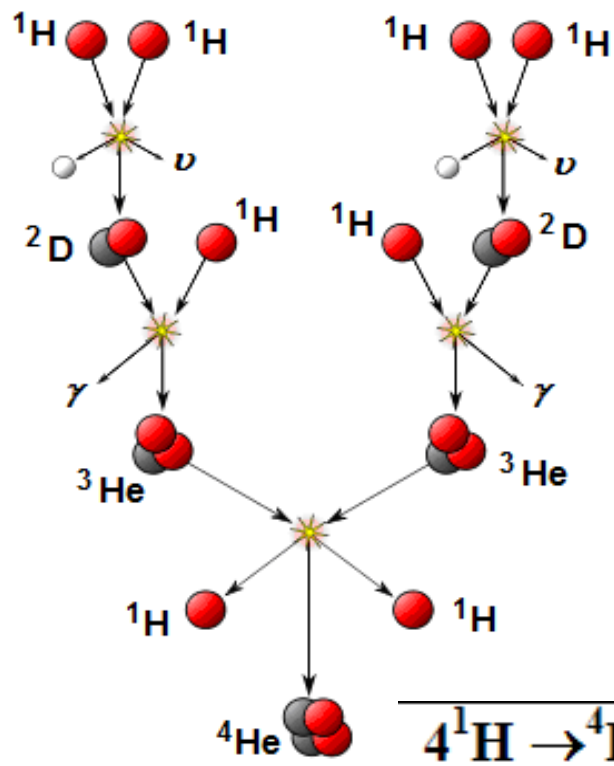
$$Q_{X(a,b)Y} = E_c^b + E_c^Y$$

$$m_b v_b = m_Y v_Y \Rightarrow v_b = \frac{m_Y}{m_b} v_Y$$

$$E_c^b = \frac{m_b v_b^2}{2} = \frac{m_Y}{m_b} \frac{m_Y v_Y^2}{2} = \frac{m_Y}{m_b} E_c^Y$$

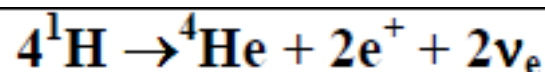
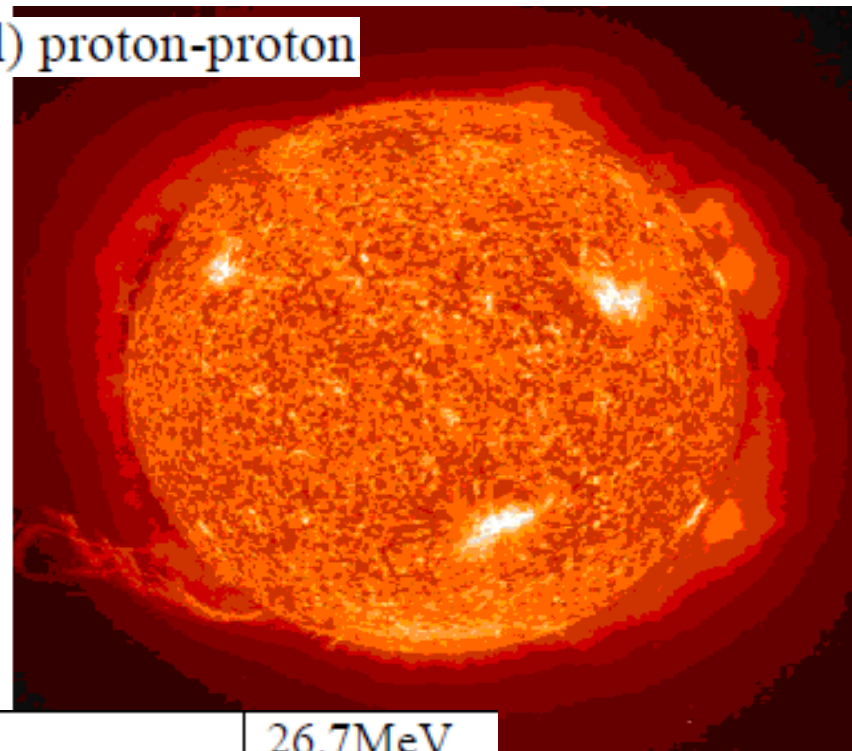
$$\begin{cases} E_c^n + E_c^{4\text{He}} = 17.6 \text{ MeV} \\ E_c^n = \frac{4.0039 - 2 \times 0.00054}{1.00893} E_c^{4\text{He}} \end{cases} \Rightarrow \begin{cases} E_c^n = 14.04 \text{ MeV} \\ E_c^{4\text{He}} = 3.25 \text{ MeV} \end{cases}$$



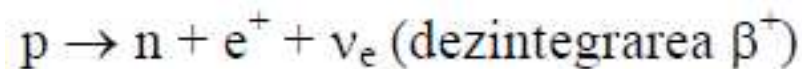
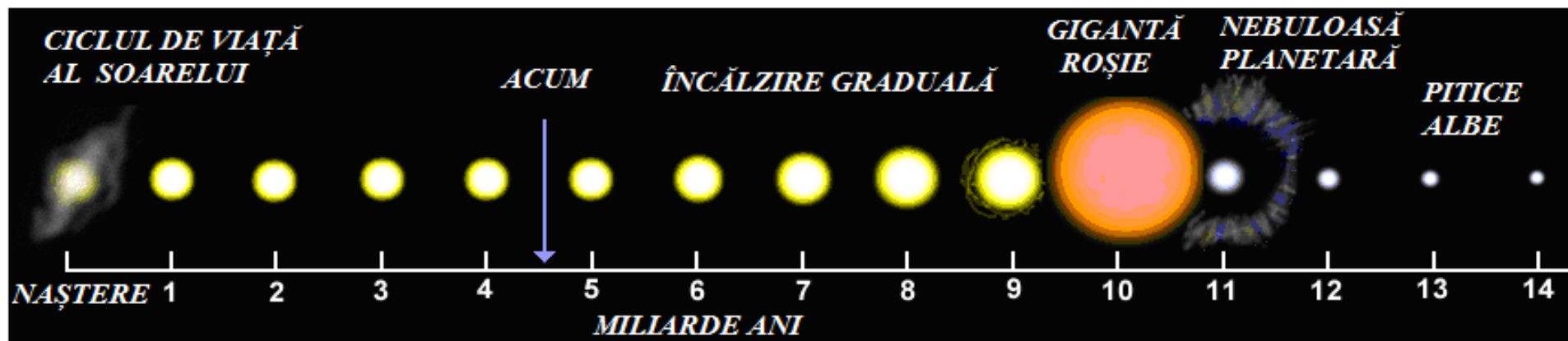


Fuziunea (ciclul) proton-proton

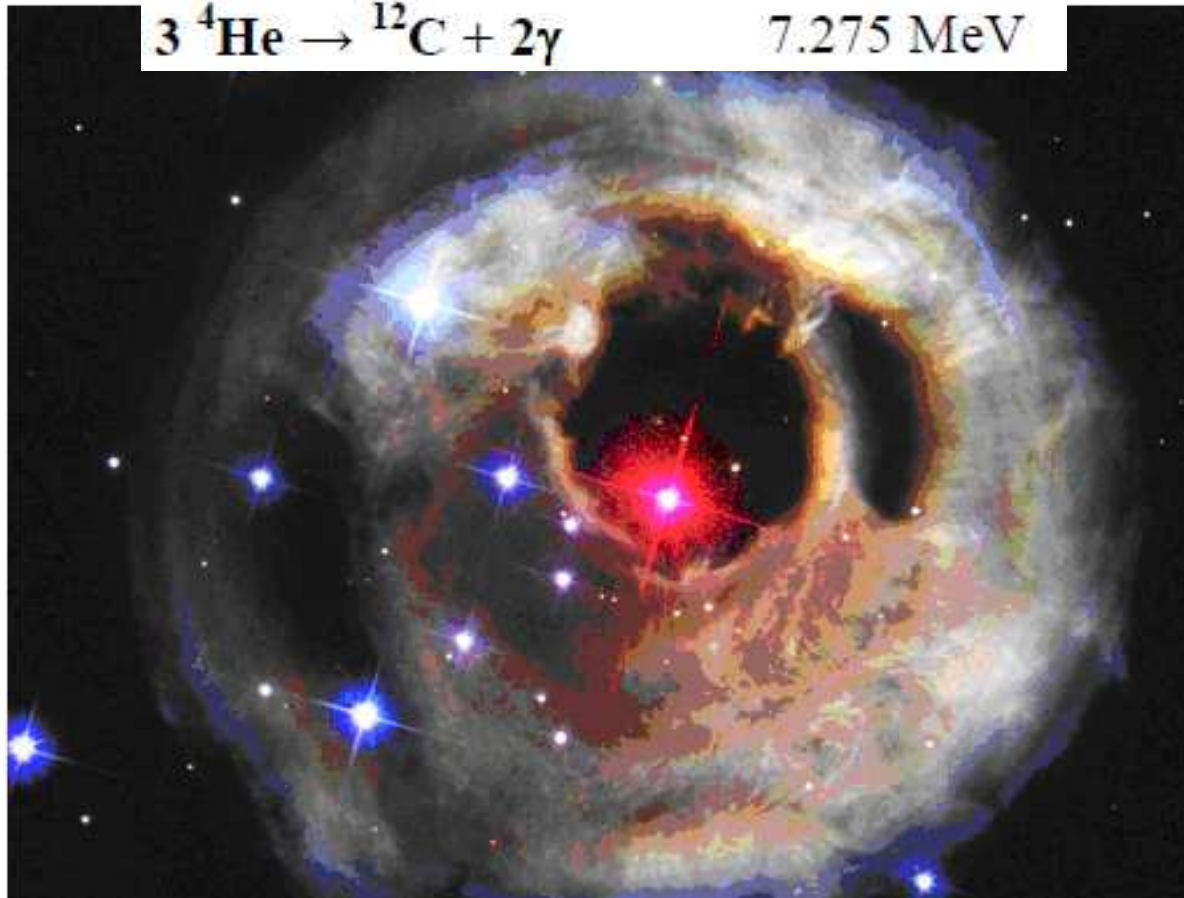
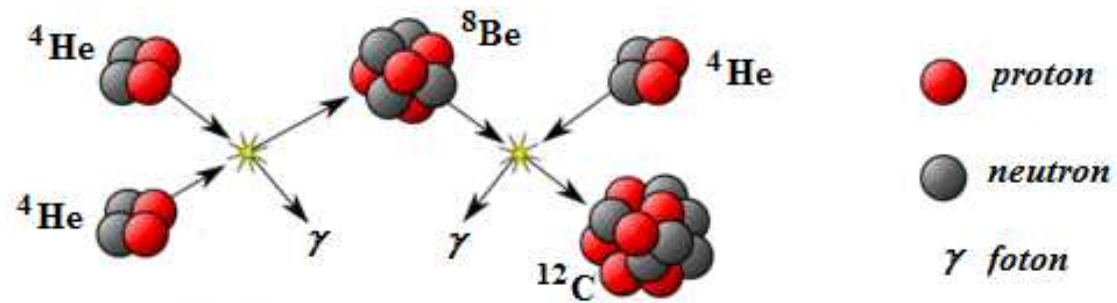
- *proton*
- *neutron*
- *positron*
- γ *foton*
- ν *neutrino*



26.7MeV

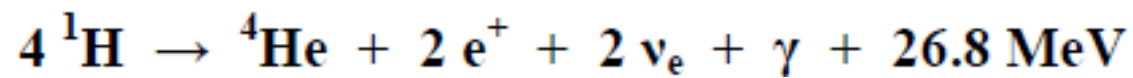
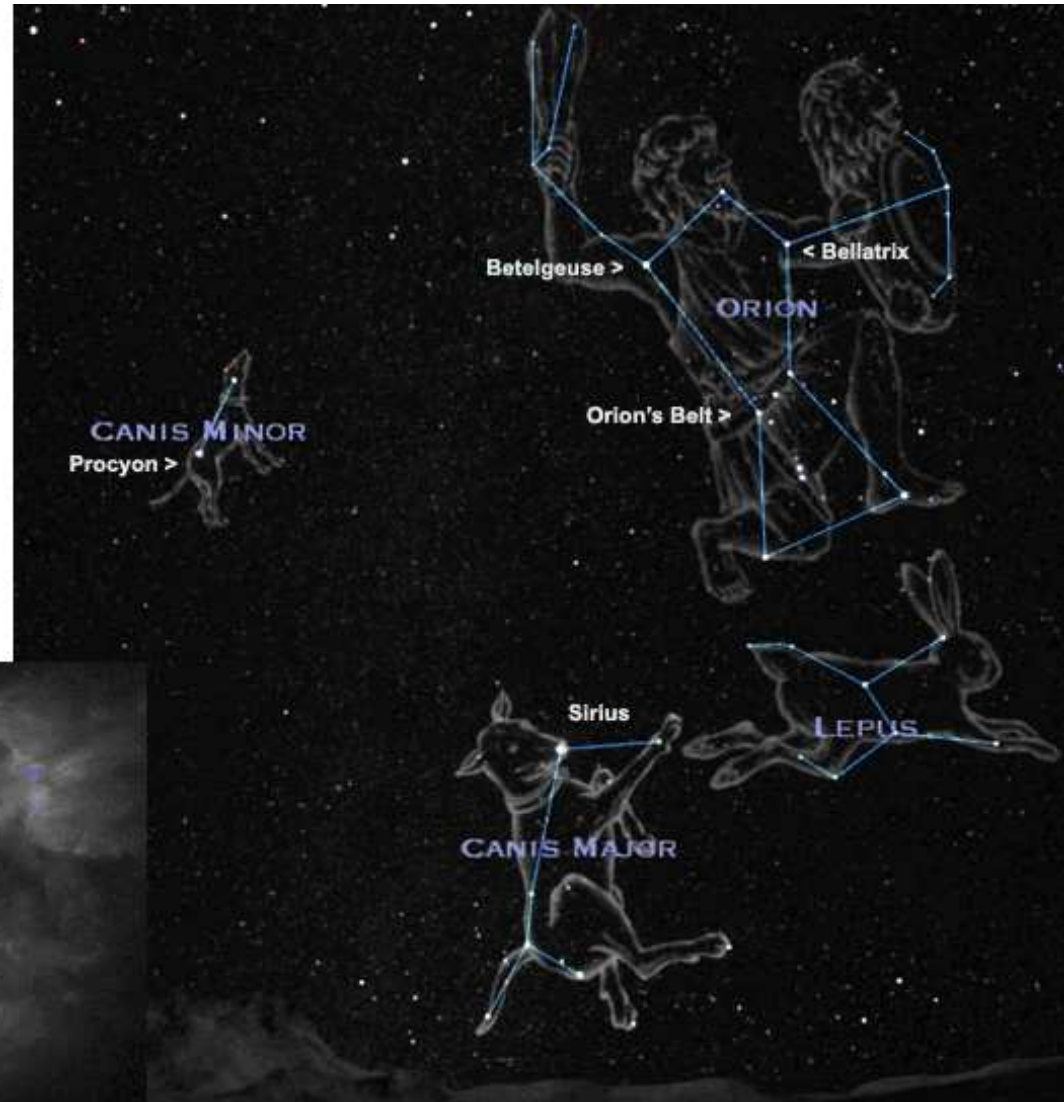
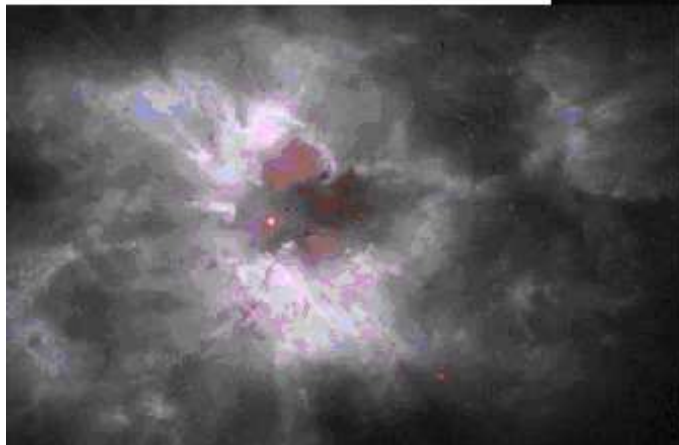
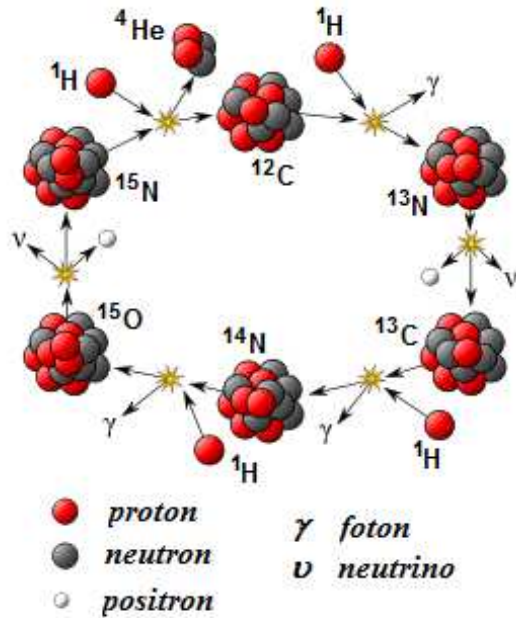


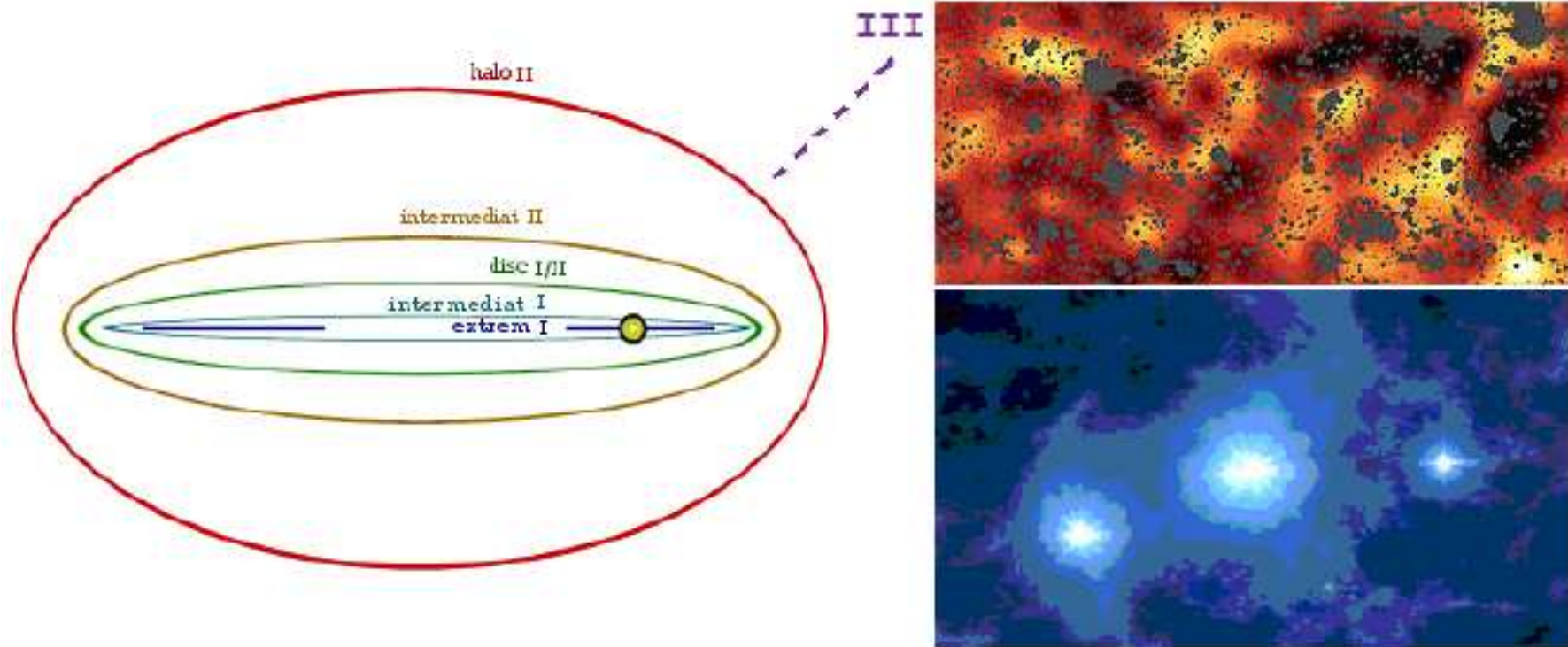
Fuziunea heliului (procesul triplu-alfa)

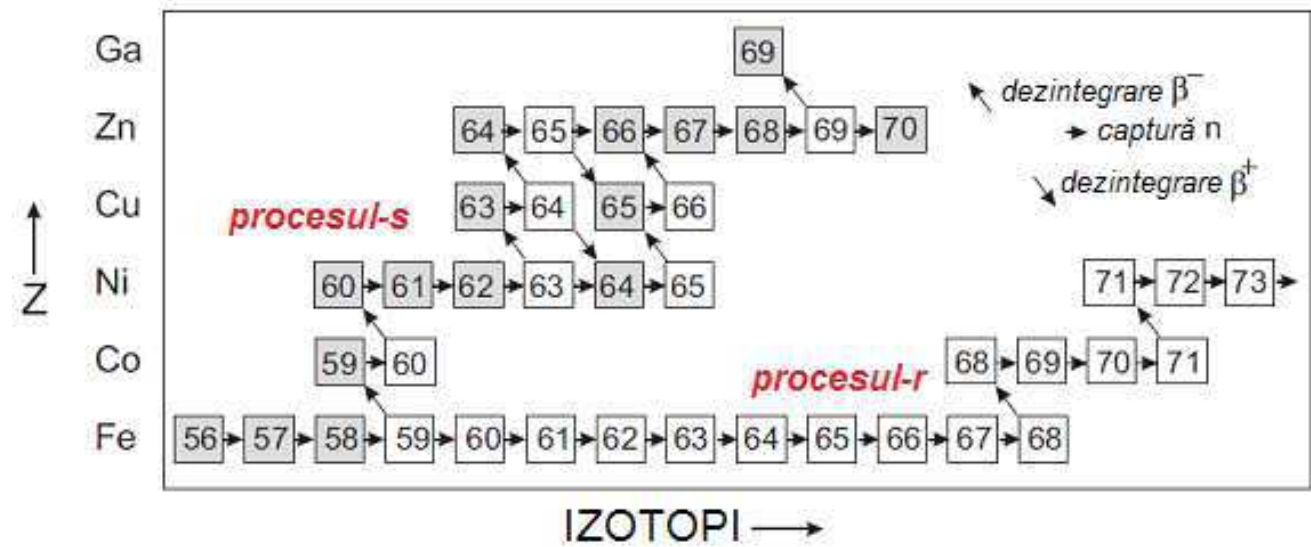
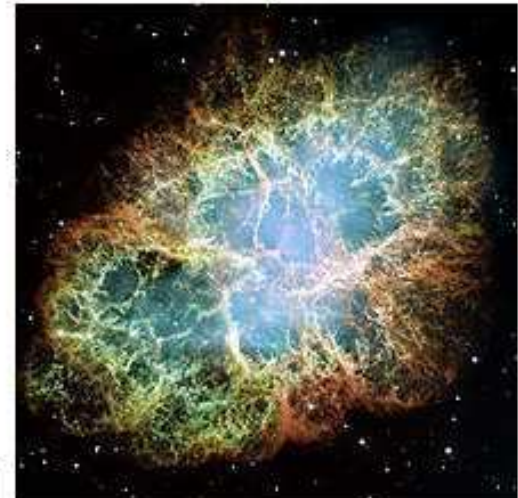
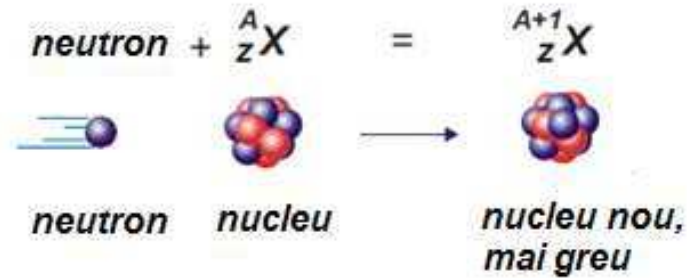


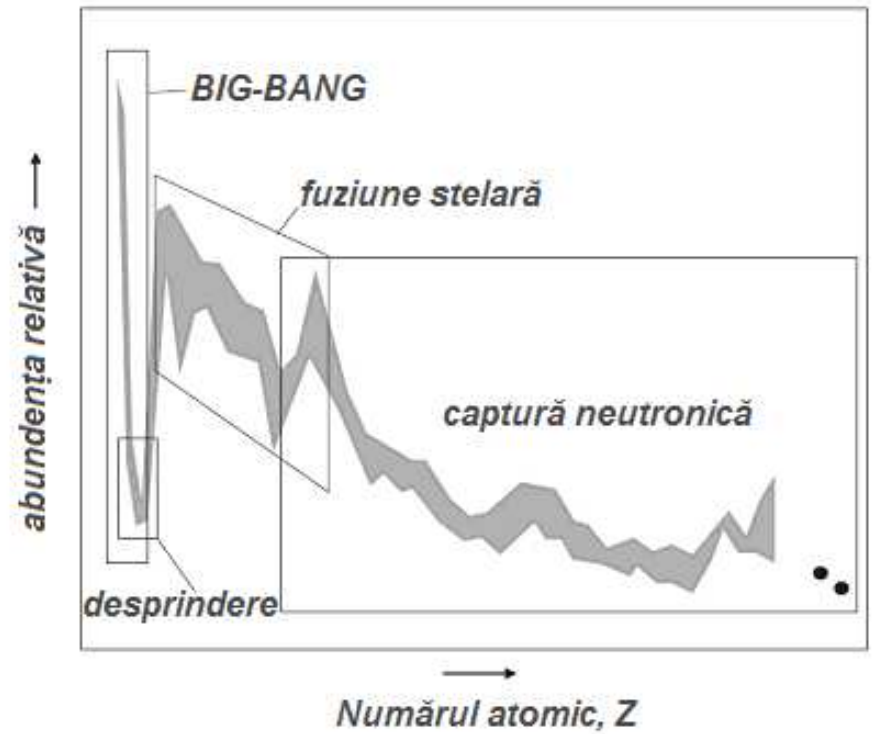
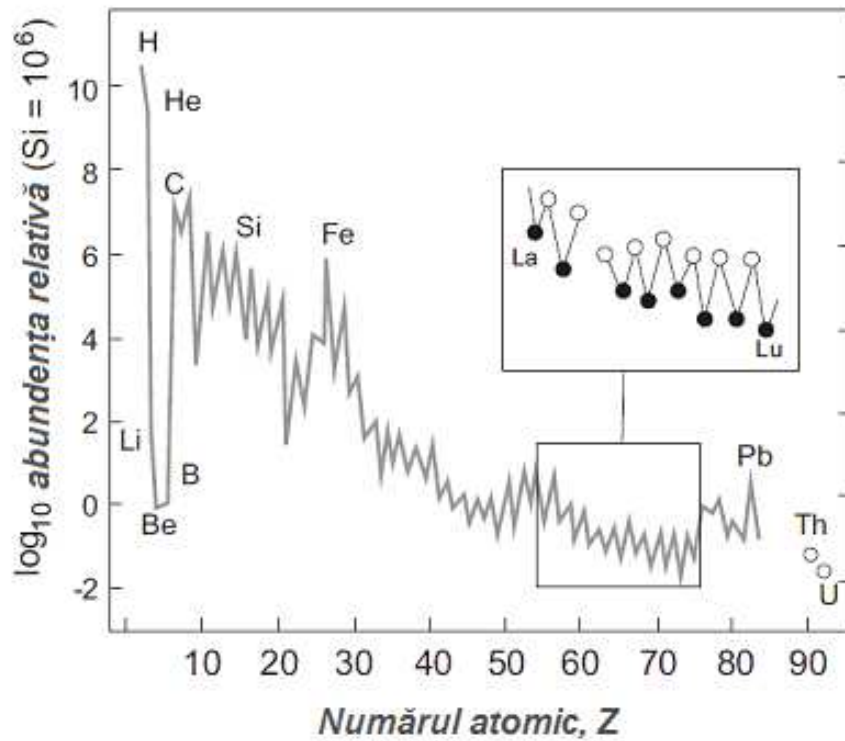
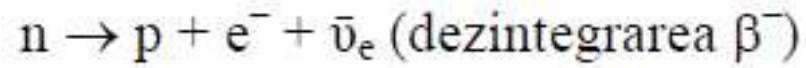
Fizica Mediului: Universul între
Energie și Nucleosinteză

Ciclul Carbonului (CNO, sau ciclul Bethe)











Enrico Fermi

20 Septembrie 1901 Roma, Italia - 28 Noiembrie 1954 (la 53 ani) Chicago, Illinois, SUA; a avut contribuții deopotrivă în fizica teoretică (statistică) cât și în cea experimentală (spectroscopie); a fost asociat la Școala Normală Superioară din Pisa (alma mater), Universitățile din Göttingen, Leiden, la Sapienza din Roma, Columbia, Chicago; advisor doctoral: Luigi Puccianti; dintre numeroșii săi studenți cei mai faimoși sunt: Ettore Majorana, Owen Chamberlain, Geoffrey Chew, Mildred Dresselhaus, Jerome I. Friedman, Emilio Segré, Richard Garwin, Bruno Pontecorvo, Leona Woods; este faimos pentru descoperirea de noi elemente radioactive prin iradierea cu neutroni, pentru reacțiile nucleare controlate, statistica Fermi-Dirac, teoria dezintegrării beta, spectroscopie, etc.; laureat al medaliei Matteucci în 1926, Premiul Nobel în Fizică (1938), al Medaliei Hughes (1942) și al premiului Rumford (1953).

Enrico Fermi



Hans Bethe

2 Iulie 1906 Strasbourg, Germania - 6 Martie 2005 (la 98 ani) Ithaca, New York SUA; a avut contribuții în teoria cuantică, teoria stării solide, fizică nucleară, cosmologie; a fost asociat la Universitățile din Frankfurt (alma mater), din München, Tübingen, Cornell, Manchester; Coordonatori doctoral: Arnold Sommerfeld; Studenți deveniți celebri: Jeffrey Goldstone, Roman Jackiw, Freeman Dyson, Robert Eugene Marshak, John Irving, P.S. Epstein; este faimos pentru fizică atomică și nucleosinteza stelară; premii importante: Medalia Henry Draper (1947), Max Planck (1955), Eddington (1961), Premiul Enrico Fermi (1961), Rumford (1962), Premiul Nobel (1967) pentru "contribuțiile sale în teoria reacțiilor nucleare, în special pentru descoperirile legate de producția de energie din stele", Medalia de Aur Lomonosov (1989), Medalia Oersted (1993), Medalia Bruce (2001); a fost numit de Dyson "rezolvatorul suprem de probleme al secolului XX!"